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Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment

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Abstract Many scholars claimed the integration of science, technology, engineering and mathematics (STEM) education is beneficial to the national economy and teachers and institutes have been working to develop integrated education programs. This study examined a project-based learning (PjBL) activity that integrated STEM using survey and interview methods. The participants were 30 freshmen with engineering related backgrounds from five institutes of technology in Taiwan. Questionnaires and semi-structured interviews were used to examine student attitudes towards STEM before and after the PjBL activity. The results of the survey showed that students' attitudes to the subject of engineering changed significantly. Most of the students recognized the importance of STEM in the science and engineering disciplines; they mentioned in interview that the possession of professional science knowledge is useful to their future career and that technology may improve our lives and society, making the world a more convenient and efficient place. In conclusion, combining PjBL with STEM can increase effectiveness, generate meaningful learning and influence student attitudes in future career pursuit. Students are positive towards combining PjBL with STEM.

Keywords Project-based learning (PjBL) · STEM (science, technology, engineering, and mathematics) · Learning attitude · Multi-function electronic vehicle

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Introduction

On the basis that the integration of science, technology, engineering and mathematics (STEM) education is argued to be beneficial to the national economy, teachers and institutes have been working to provide the best package of integrated education (David and Sharon 2006). The study by Dewaters (2006) showed that students welcomed integrated STEM courses and perceived that such courses helped to resolve problems in daily lives. The students also indicated that these STEM course could improve their learning abilities. The results suggest that students need to learn advanced mathematics and many kinds of scientific knowledge in order to meet the requirement of engineering and technology in the future. Having this kind of understanding, more countries now pay attention to students' learning situations and hope that they can be improved through designing appropriate environments for STEM teaching.

The pedagogic concept of project-based learning is different from traditional learning in that it tries to develop students into active learners who actively acquire necessary knowledge to resolve problems that appear in the project, not as passive learners who always receive second hand knowledge (Thomas 2000). The project-based learning (PjBL) approach is one that focuses on organizing self-learning in an empirical project. Through practical activities, interactive discussions, independent operation and/or team cooperation, students reach the planned target and establish their own know-how. In this system, teachers play the role of facilitator. In this highly competitive era, there is no doubt that what the youth possess today will have a certain impact on what societies will look like in the future. How to assist students in establishing appropriate and effective learning attitudes has became an important task. In this study, students were encouraged to resolve problems with scientific and mathematical methods towards the purpose of structuring their knowledge base. Students could also combine technological tools with engineering concepts to accomplish the project. Through integrating science, technology, engineering and mathematics into a project-based learning pedagogy, this study aims to understand students' learning attitudes and motivations, to enhance their abilities to reuse knowledge and to strengthen their learning abilities.

Literature review

Project-based learning (PjBL)

Project-based learning mainly involves areas of constructivism (Hmelo-Silver 2004), situated learning Theory (Zastavker et al. 2006), cognitive psychology (Hmelo-Silver 2004) and the concept of course integration (Laughlin et al. 2007). This is an approach for students to construct knowledge through teamwork and problem-solving with scientific methods (Krajcik et al. 1999). Project-based learning has been a category of pedagogical practice for years, and involves a wide range of scientific areas where learners usually concentrate on group learning and presenting various outcomes. In the studies by ChanLin (2008) and Karaman and Celik (2008), results indicated that learners in project-based learning performed better in skill development, general ability and knowledge compilation than those who did not use project-based learning. In addition, it is argued that project-based learning helps to increase students' positive learning attitudes towards technology (Mioduser and Betzer 2007) and science (Catherine and Barry 2008). To ensure the positive effect of project-based learning is achieved, attention must be paid to factors such as materials for project-based learning, the extent to which the project is relevant to the level of the learners, the complexity of the project, provision of appropriate support, the learners' prior knowledge and teamwork skills (Thomas 2000).

In recent years, research (Laughlin et al. 2007) at universities has concentrated on working out a pedagogy that integrates the courses of science, technology, engineering and mathematics. The rationale behind this concentration is to enhance the sense of achievement in learning, to improve learning attitudes and to increase learning continuity (Springer et al. 1999). In the study by Porter et al. (2006), an innovative system of STEM education for universities is proposed. They argued that through a system of multidisciplinary teaching, students may learn faster. Relevant research in Taiwan is only at the infant stage. More research is needed to investigate the impact of the integration of these subjects on the learning attitudes of students, and to provide reference to subsequent course design.

Student attitude towards science, technology, engineering and mathematics

Attitude is made up of emotion, cognition and intention (Myers 1993). It can also be viewed as individual beliefs about the attributes of a particular object (Fishbein and Ajzen 1975), and may be influenced by various other attributes (Ajzen 2001; Crano and Prislin 2006). In the point of view of Osborne et al. (2003), student attitude towards enrolling in a course is a strong determinate of a student's choice in pursuing future careers. As a result, a better understanding of student attitude and the relationship between course choice and future career choice would lead to instructional and curricular changes that may support and enhance students' learning of difficult subjects such as science, technology, engineering and mathematics.

Science

This study focused on exploring student attitudes towards science in order to understand student interest and self-concept in learning science. Various factors, such as teachers, parents and peers, were considered to examine the influence on student attitudes towards science. In particular, teachers' instructional pedagogy and learning environment were the most widely discussed. Piburin and Baker (1993) mentioned that one of the reasons for students' negative attitudes towards science was due to the abstract nature and complexity of science. Also, Mamlok-Naaman et al. (2005) found that student attitudes towards science were mainly influenced by interest and emotion. They concluded that students are not willing to take a science class seriously when they found it to be boring. These arguments may imply that teaching instruction is the major reason for low interest and negative attitudes towards school science learning in current curricula worldwide. This may be due to the fact that science teachers focus mainly on theoretical understanding rather than practical work, which reduces the opportunities for students to implement their science experience. Nolen (2003) argued that if instructors emphasize memorization in science learning, it may lead students to view science as a boring and impractical subject. In the viewpoint of Osborne and Collins (2000), students are willing to learn science in a practical way, which may enhance personal autonomy. Similar results were also found in George's (2006) study, which argued that when students are able to practice the science knowledge that they have learned in school and understand the utility of science in their daily lives, their interest in science may rise. As mentioned above, the development of positive attitudes towards science can motivate students' interest in science education and science-related careers (Crawley and Coe 1990;

Norwich and Duncan 1990). Thus, it is important to develop appropriate instructional strategies that enhance students' interest and attitudes towards science.

Technology

Students' attitude towards technology is a popular subject. In the study by Hendley et al. (1995), technology was recognized as the most popular subject. Rees and Noyes (2007) mentioned that students (especially male students) present positive attitudes towards technology. In the study by Boser et al. (1998), student attitudes towards the instructional approach to technology were measured. The results suggest that instructional approaches and curricular content may influence student attitudes and their future career decisions. Also, Jenkins (2006) indicated that students prefer to work with new technologies. The students mentioned that working with new technologies is interesting, and technology is beneficial and important to society, medical treatment, and living, although some environmental issues caused by technological development were a concern.

Engineering

Studies that discuss student attitudes towards engineering present controversial results are as below. Seymour and Hewitt (2000) argued that the major reason that students quit engineering classes is due to the decrease of interests in science, which is the fundamental motivation for learning engineering. Another major reason is that subjects in other disciplines attract students. However, other studies revealed that students consider engineering to be an interesting and useful subject. In the study by Hilpert et al. (2008), on attitudes of first-year students towards engineering, the results indicated that students were enjoying the study of science and mathematics that are fundamental to engineering. They had positive attitudes to engineering due to its contribution to society, and they were willing to engage in engineering-related careers. From the abovementioned discussion, students' interest may have a direct influence on student attitudes towards engineering. Student attitudes and perceptions may also further influence their choice to continue learning in an engineering curriculum.

In considering the enhancement of student interest to learn engineering and to further increase their positive attitude, influential factors ought to be considered in engineering curricula. Besterfield-Sacre et al. (1999) examined student attitudes towards engineering according to their gender and ethnic background. They concluded that student gender and ethnic background influence attitudes.

Current engineering courses usually focus on theoretical understanding rather than practical application in Taiwan. However, engineering in a social perspective requires practical application skills in terms of communication and interpersonal skills (Felder et al. 2002). This issue may require that the teaching instrument in the engineering curriculum be altered in Taiwan.

Mathematics

Regarding attitudes to mathematics, students presented similar viewpoints as attitudes towards science. Mathematics is usually found to be a less popular subject (Bragg 2007), and students' negative attitude towards mathematics can grow with age (Utsumi and

Mendes 2000). However, students mentioned that mathematics is still advantageous in some ways. First, students in the study by Hillel and Perrett (2006) determined the concept of mathematics from a micro perspective to be an emphasis on calculating numbers, and from a macro perspective to be a system for daily life and a way of thinking. Moreover, some students mentioned that "mathematics is the language of science" (Goldin 2003. p.180), and others recognized mathematics as a primary tool for the application of engineering (Bingolbali et al. 2007). On the other hand, mathematics, in terms of learning, is a difficult subject. When learning support is insufficient in a mathematics curriculum, students' learning interest may easily decrease, and further causes an increase of negative attitudes (Stone et al. 2008).Likewise, Walsh (2008) pointed out that students' achievement in mathematics is determined by the extent to which they are anxious about mathematics.

STEM

From the previous discussion, study results (ex: Goldin 2003; Seymour and Hewitt 2000; Singh et al. 2002) revealed that the subjects of science, technology, engineering and mathematics are closely related to each other. STEM courses and programs are developed to generate meaningful learning through integrating knowledge, concepts and skills systematically. Also, because STEM courses and programs are able to enhance student competence in STEM professions, and to provide better understanding of scientific and engineering work (Springer et al. 1999), research at universities in recent years has concentrated on working out a pedagogy that integrates the courses of science, technology, engineering and mathematics. The rationale behind this concentration is to enhance the sense of achievement in learning, to improve learning attitudes and to increase continuity in learning (Springer et al. 1999). In the study by Porter et al. (2006), an innovative system of STEM education for the university level was proposed. Through the idea of multidisciplinary teaching, they argued that students might learn faster. Relevant research in Taiwan is only at the infant stage. More research should be done to investigate the impact of the integration of these subjects on the learning attitude of students and to provide reference to subsequent course designs. Thus, the present study applied an integrated STEM activity in PjBL in order to provide students an opportunity to utilize and integrate the knowledge of the four subjects, and furthermore enhance their learning interest in STEM. Through integrating science, technology, engineering and mathematics into a project-based learning pedagogy, the students' reflection on their knowledge of STEM could help learners understand the relationship between their learning and problem-solving goals and could improve learning interest (Hmelo-Silver 2004; Salomon & Perkins 1989).

Methods

The main purpose of this study was to understand students' learning attitudes towards science, technology, engineering and mathematics through the pedagogy of project-based learning (PjBL). Conventional wisdom concerning the PjBL principle was employed by emphasizing artifact creation, based on authentic and real life experiences with multiple perspectives, as part of the learning outcome. This study experimented with a short term PjBL design that required more learned knowledge to complete its project. Specifically, this experiment was designed using the currently popular combination of PjBL with STEM, which is also new. The five-week cross-school competition entitled "multi-function electric vehicle" in order to integrate STEM, was held during the 2008 winter break. The design of the project of electric vehicle included multi-disciplinary components of electrical engineering, mechanical engineering, machine dynamics, electronics, robotic kinematics, automation, application and practice of mechatronics, energy, motors, etc., which were related to the curricula that students had learned in their vocational senior high school courses. The goal for the PjBL activity- of producing the vehicle in this study provided an opportunity for the participating students to learn through group effort, group discussion and continuous examination. It also facilitated application and integration of STEM knowledge in the students to enhance their abilities of problem solving and knowledge integration.

In total, thirty-first-year-students (five groups) with engineering backgrounds from five institutes of technology in Taiwan were recruited. To finish the electric vehicle, students had to actively apply their STEM knowledge and to be collaborative using team work. The students were organized into five teams of six members each. In order to enhance student interaction, a web-based platform was established. After the activity, a questionnaire and semi-structured interviews were adopted to investigate student attitudes.

Derived from other attitude questionnaires, this STEM attitude questionnaire was examined by three experts. The reliability of the questionnaire was first tested and confirmed in a pilot study with more than 100 students from six different engineering disciplines. A five-point Likert-type scale was used, ranging from 1 (strongly disagree) to 3 (neutral) to 5 (strongly agree). Three items with low Cronbach's alphas were deleted, and thirty-eight items remained in the questionnaire. The overall reliability of the questionnaire is high (Cronbach's $\alpha = 0.94$), and the reliabilities of the dimensions of science (S), technology (T), engineering (E) and mathematics (M) are 0.72, 0.81, 0.79 and 0.89, respectively. The questionnaire was analyzed by One-Sample t-test to examine the direction (positive vs. negative) of the student attitudes towards the four subjects of STEM. Furthermore, a Paired-Sample t test was used to understand the change of student attitudes to STEM before and after the PjBL activity. In order to gain a deeper understanding of student attitudes, a semi-structured interview was conducted after the project. Two interviewees were selected from each group; they were the students who had the highest discussion frequency on the web-based platform. All the interviews were tape recorded and then transcribed. A uniform set of rules were applied to transcript coding. For instance, F5: 046–049 meant that the data was from Line 46 to Line 49 in the transcript of Group 5. Afterwards, transcripts were conceptualized through open coding, connected with each other through axial coding and then integrated through selective coding. Finally, categories and contents that resulted from the process of coding were elaborated upon in the next section.

Results

The present study investigated student attitudes and the change of student titudes towards the four subjects of STEM in a PjBL activity. The results of the questionnaire analysis are as following:

Students had a positive attitude towards STEM. Technology is the most popular subject at the pre-learning stage, while engineering was recognized as the most popular subject after learning

The questionnaire results indicated that students had positive attitudes towards STEM. According to Table 1, descriptive statistics (mean, standard deviation) and one sample

Table 1 Analysis of one-sample t test regarding students' learning attitudes towards STEM

Participant	Number	Subject	Pre-test			Post-test		
			Mean	*SD*	t	Mean	*SD*	*t*
Students	30	Science	3.857	0.422	11.130***	4.020	0.418	13.364***
		Technology	3.926	0.338	14.996***	3.978	0.517	10.368***
		Engineering	3.804	0.482	9.136***	4.078	0.459	12.869***
		Mathematics	3.647	0.468	7.566***	3.753	0.666	6.197***
		4 subjects	3.808	0.379	11.668***	3.957	0.454	11.551***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

t test were adopted to investigate students' learning attitudes after participating in the STEM project activity. One sample *t* test analysis was used to compare the learning attitudes of students with an answer of "3", the "neutral" point on the five-point Likert scale, towards Science, Technology, Engineering and Mathematics. In general, the results showed that student attitudes towards the four subjects of STEM were positive and significant (M = 3.957, $SD = 0.454$, $t = 11.551$, $p < 0.001$). Student attitudes towards science, technology, engineering and mathematics were positive and significant. In particular, students had the most positive attitude to technology at the pre-test stage (M = 3.926). The results have changed by the post-test stage in that engineering became the most popular subject (M = 4.078). It is noteworthy that mathematics was the least popular subject at both pre- and post-test stages.

Students had the most significant changes in attitude towards engineering before and after the PjBL activity

In the present study, a Paired-Samples t-test was adapted to measure the change of students' attitude towards STEM. The results indicated that student had significant change only in the attitude to learning engineering ($t = -2.619$, $p < 0.05$). In regard to science, technology and mathematics, students' positive attitudes increased slightly although the changes were not significant. The results suggest that PjBL can facilitate the enhancement of learners' positive attitudes towards STEM, particularly in the subject of engineering (Table 2).

Table 2 The difference between the student pre-test and post-test attitudes (n = 30; $df = 29$)

Subject	Pre-test/post-test	Paired Differences M (*SD*)	*t*
Science	*Pair 1 S-pS*	−0.163 (0.483)	−1.852
Technology	*Pair 2 T-pT*	−0.052 (0.517)	−0.550
Engineering	*Pair 3 E-pE*	−0.274 (0.573)	−2.619*
Mathematics	*Pair 4 M-pM*	−0.107 (0.645)	−0.906
4 subjects	*Pair 5 Overall-pOverall*	−0.145 (0.463)	−1.719

* $p < 0.05$

Asterisk denotes the statistical significance of results when testing hypotheses, and the *p*-value is less than the specified significance level of 0.05

At the 5% significance level, the data provides sufficient evidence to conclude that the mean of post-test is higher than the mean of pre-test

Analysis of interview transcripts was used to investigate both student attitudes towards science, technology, engineering and mathematics, and how the students applied STEM knowledge in the PjBL activity. The results are as follows:

Students had positive attitudes towards STEM, and they recognized the importance of STEM in the science and engineering disciplines

In regard to student attitudes towards science, the quantitative data revealed that student attitudes at both pre-test (M = 3.857, $SD = 0.422$, $t = 11.130$, $p < 0.001$) and post-test (M = 4.020, $SD = 0.418$, $t = 13.364$, $p < 0.001$) stages were positive and significant. Similar results can be found in the interview, showing that students are positive about learning science. Students indicated that *"they are willing to learn science initiatively (F5:249)"*. They also indicated *"they preferred to learn and* obtain science related knowledge from practical experiments (F4:011, F3:036), and previous experience (F4:011, F5:030)". They also mentioned "Science is beneficial *and can be generally applied in daily life (F2:088, F3:036)"*. They further suggested *"the possession of professional science knowledge is beneficial to one's future career (F2:114, F3:044, F5:263)"*. As a result, students have strong interests in learning science, and they prefer to learn practically rather than theoretically.

The quantitative data showed that student attitudes towards technology at both pre-test (M = 3.926, $SD = 0.338$, $t = 14.996$, $p < 0.001$) and post-test (M = 3.978, $SD = 0.517$, t = 10.368, $p < 0.001$) stages were positive and significant. The analysis of interviews demonstrated that student attitudes towards technology were basically positive.

Students indicated *"they are learning technology related knowledge mainly from formal courses at university (F5:061), and they are interesting in learning technology, particularly when learning is processed through doing practical work (F1:068, F3:092, F4:444).* Students also mentioned *"they are very much willing to be engaged in technology related industries in the future (F5:061, F1:083-094, F3:086, F4:437)"*.

However, some negative opinions about technology were found. The reason for the findings may be due to student thinking such as, "technology may improve our *society and lives making the world more convenient and efficient, and humans can not live* without technology (F3:058, F4:249, F5:053, F1:040, F2:157)", combined with, students also mentioning that "technology is somehow harmful to human life, health *and environment (F2:169, F3:062), such as the hacker intrusion and the effect of electromagnetic waves on the human body (F1:034, F4:254, 274)"*. Such consequences may cause *"the loss of social harmony and nuclear war (F2:179)"*. As a conclusion, students recognized that although technology is important for human life, *"decreasing pollution is an important issue for current technological development (F5:087), such as the invention of hybrid-electric vehicles (HEVs) which can reduce pollution and save energy resources (F5:085)"*.

Regarding quantitative data, the results revealed that student attitudes towards engineering were positive and significant at both pre-test (M = 3.804, $SD = 0.482$, $t = 9.136$, $p < 0.001$) and post-test (M = 4.078, $SD = 0.459$, t = 12.869, $p < 0.001$) stages. The difference between student attitudes was also significant (M = −0.274, $SD = 0.573$, $t = -2.619$, $p < 0.05$). From the interview, similar results were shown that students were positive in their attitudes towards engineering. They mentioned *"engineering is the application of the scientific principle and the skill to solve realistic problems."* The application has *"great benefits to our daily lives in terms of convenience, urban beautification and economic improvement (F3:100), such as bridges that cross oceans (F3:096), undersea tunnels (F3:098) and earthquake shock absorber systems for buildings (F4:*

558)". On the other hand, students suggested that *"engineering knowledge is complex and difficult to learn (F4: 600) since it requires certain competence in science and mathematically logical concepts (F5:117, F4: 602)"*. Also, *"engineering is a subject that emphasizes more practical experiences (F5: 107)."* For future career pursuit, the majority of students indicated that *"they are willing to work in engineering related industries (F3: 120, F2: 264) due to its professionalism and difficulty for replacement (F5:141)"*.

In regard to student attitudes towards mathematics, quantitative results indicated that students had positive and significant attitudes towards mathematics at both pre-test(M = 3.647, $SD = 0.468$, $t = 7.566$, $p < 0.001$) and post-test (M = 3.753, $SD = 0.666$, $t = 6.197$,$p < 0.001$) stages. From the analysis of interviews, the majority of students had "positive attitudes and showed least interest in mathematics. *(F1:152, F5:201, F4:126,F3:159)"*. They indicated in the interviews *"the current engineering and technology courses require logic and mathematics (F1:176–180, F5:235)"*. Due to this, *"mathematics is the foundation and essential competence of the science and engineering disciplines (F3:173, F2:402)*. Some students also mentioned that *"they dislike mathematics due to its difficulty to be comprehended, but they will still learn mathematics because it is an important subject (F2:402, F4:672)"*.

During the PjBL activity, students applied the conceptual knowledge of STEM, particularly in engineering knowledge

In the process of producing electronic multi-functional vehicles in the PjBL context, students applied knowledge in the four subjects of science, technology, engineering and mathematics. From the interviews, students suggested that *"the four subjects of science, technology, engineering and mathematics were highly interrelated to each other (F3:230, F4:546)"*. Also, *"the priority for the participant in the multi-functional vehicle activity was to possess sufficient prior knowledge of STEM (F3:228), and then to integrate the knowledge in goal orientation."* Others also mentioned that *"through the activity, we were able to implement our prior knowledge of science into practice (F3:046), and improve our ability of analysis in engineering(F3:104)."* More specifically, the interview results indicated that students more frequently applied engineering knowledge than the three other subjects during the activity. Some students stated *"engineering knowledge was fully applied during the production process of the multi-functional electric vehicles (F5:111, F1:112), as others mentioned that "they used more engineering related knowledge in the activity (F2:013–020,F5:105)"*.

In another part of the interview, students demonstrated how they applied STEM knowledge during production of the multi-function electric vehicle (see Table 3). First, they indicated that *"science knowledge was mainly applied to produce sound while the vehicle is moving, such as: using single chip to produce sound through frequency*

(F5: 037)". Also, *"concepts of science were also used to design the electric solar vehicle (F5:042)"*. Regarding the use of technology knowledge, students *"applied knowledge related to technology to write a program in order to modify the functions of the vehicle (F5:042)."* They also *"used the knowledge of technology to design a solar panel and to link up to a stepping motor (F2:219–221, F5:064)"*. Furthermore, the engineering related knowledge *"was fully employed in producing the electric vehicle by combining the photo resistors, the movement of the stepping motor and the battery (F5:108, F1:112)"*. Finally, Students also mentioned that they "*applied mathematic knowledge in engineering and technology to figure out designs and solve problems in a logical manner (F1:176–*

Table 3 The description of student producing multi-function electronic vehicle through applying STEM knowledge

Group	Science/mathematics	Technology	Engineering
Group 1 	1. Use Lever Principle to make reduction bevel gear system 2. Use Solar Concentrator Module to decompose the water of Hydrogen–oxygen fuel cell into hydrogen and oxygen 3. Use Archimedes' Principle to calculate volume and test buoyancy for floatation in order to move in water	1. Use the Wireless Remote Controller at frequency of AM627.255 to send out single, and then transfer to Voltage Pulse for controlling the servomotor 2. The servomotor controls the revolutions and the angle of direction change based on the quantity of Pulse Voltage 3. After testing, the 7.2v direct current (DC) motor is used 4. Use a 16 gear reduction bevel gear system to change direction, reduce speed and increase torque 5. The Solar Concentrator Module is used as the main power of Hydrogen-oxygen fuel cell 6. The circuits of the LED indicator lights are installed on the motor. The series and parallel circuits are connected with the LED lights. The LED lights thus turn green when the vehicle goes forward, and turn red when it goes back	1. A cross-country vehicle chassis is used as the body to increase the height of the vehicle 2. Larger tires are used to move on rough terrain 3. Integrate the solar panel and Hydrogen–oxygen fuel cell 4. Design the circuits of the LED indicator lights for going forward and back 5. Spread silicone around the tire for moving in water 6. Use Styrofoam sheets, boards and buoys to produce floatation 7. Use a "small fan" for heat sinking

Table 3 continued

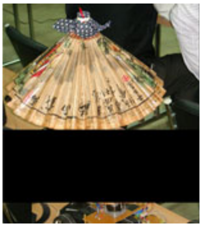
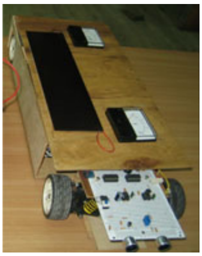
Group	Science/mathematics	Technology	Engineering
Group 2 	1. Use solar panel to store electricity in the battery 2. By using Graph Theory, the greatest sunshine angle can be determined through Photoresistance in order to produce the best power 3. Use different frequency of square-wave signal to design electronic sound program of the horn	1. Use Microchip dsPIC-16bit to adjust two-phase stepper motor via the feedback of Photoresistance to rotate the solar panel to the best sunshine angle 2. Use single chip to drive the horn for electronic music 3. The motor-driving circuit board is produced by welding the electronic component and IC on the circuit board	1. The vehicle is designed with a tracking system for solar energy and with electronic music of Hakka folk songs 2. The solar energy photoelectric template was designed to absorb electricity for reducing cost and saving energy 3. Wood is the major material. A light paper umbrella is also used as a support to make the motor turn smoothly and to keep the vehicle body's balanced 4. The motor-driving circuit board is designed
Group 3 	1. Remote control, self-propulsion started by whistling and automatic lighting device are included with regard to controlling the vehicle body. 2. Use voltage law and basic scientific markers to calculate color code resistance and capacitance	1. Use sound sensors, light sensors and infrared sensors to strengthen the functions of the self-propelled vehicle 2. Planning the disposition of the motor and calculating the length, width and height in advance, then use iron plate to produce the vehicle body	1. Self-propulsion: The vehicle can move forward, reverse, right turn and left turn by using photoelectric sensors to sense the black track 2. The function of infrared remote controller 3. Light source tracking function and sound controlling function 4. Use LED lighting module to design automatic lighting for energy saving
Group 4 	1. Concepts of energy saving and transfer for solar to generate electronic power 2. Use ultrasound to examine distance	1. Produce the ultrasonic obstacle avoidance system to reinforce the function of self-propulsion 2. Apply Solar Generator to recharge a self-propelling vehicle 3. Produce a self-propelling vehicle with a single chip as the controlling core 4. Use DC motor to drive the leather belt forward for driving the generator gear	1. Design a self-propelling vehicle with a single chip as the controlling core, and assisted by using ultrasonic sensor and solar generator 2. The material of the vehicle body includs vehicle body structure, solar panel, driving controller, generator, and ultrasonic sensor. The goals of the vehicle body are simple, practical and convenient

Table 3 continued

Group	Science/mathematics	Technology	Engineering
Group 5 	1. The multi-functional vehicle is designed and produced based on principles of a stacker combining the characteristics of stacker and crane 2. The jig is constucted by robot arms. Before that, the bearing weight of the jig was figured out 3. The material of vehicle structure is aluminum alloy. The bearing weight was also calculated in order to carry each part of the vehicle	1. Use aluminum strip and aluminum sheet to produce vehicle body and the moving platform that keep the balance of the vehicle body 2. The 12 V DC motor was used as the major power for vehicle to be driven and the platform to be moved 3. The four-axis robot arms were driven by four motors, and was controlled by a single 8051 chip 4. The remote controller was produced by the combination of relay, remote control module and the wiring	1. Design the function of remote controller for operating the vehicle, machines, tools and robot arms 2. The major concepts of design include the vehicle structure, drive, clip and remote controller 3. The vehicle moves through front wheel drive 4. Design the four-axis robot arms 5. Regarding the circuit, eight relays are used to control the vehicle

180)". Figure 1 shows the design and production of the electric vehicle of group A through integrating STEM related knowledge.

Discussions and conclusions

The present study adopted a PjBL strategy to help students integrate and apply STEM knowledge in a practical experiment. The purpose of the study was to enhance students' learning attitudes towards STEM, and to inspire students' learning interest and learning autonomy.

In this present study, through the results of both questionnaire and interview, students presented positive attitudes towards science. A slight change of student attitudes towards science was found during the PjBL activity. The majority of students indicated that science could be applied to solve real world problems and to increase effectiveness in daily lives. The possession of scientific expertise was thought to be beneficial for pursuing future careers and was the major reason to inspire student interest and intention in learning science. In terms of learning strategies, students were more likely to acquire scientific knowledge through practical work. The PjBL strategy was thus applied in the present study in order to promote students' intention in learning science related knowledge. Osborne and Collins (2000) and George (2006), argued that students were more willing to learn science knowledge via practical methods. They argued that students' personal autonomy and interest in learning science may be enhanced through PjBL strategy.

Considering technology, students revealed positive attitudes in their questionnaire results. However, from the interviews, students presented contradictory arguments. While some students thought technology was beneficial for real life, others mentioned some

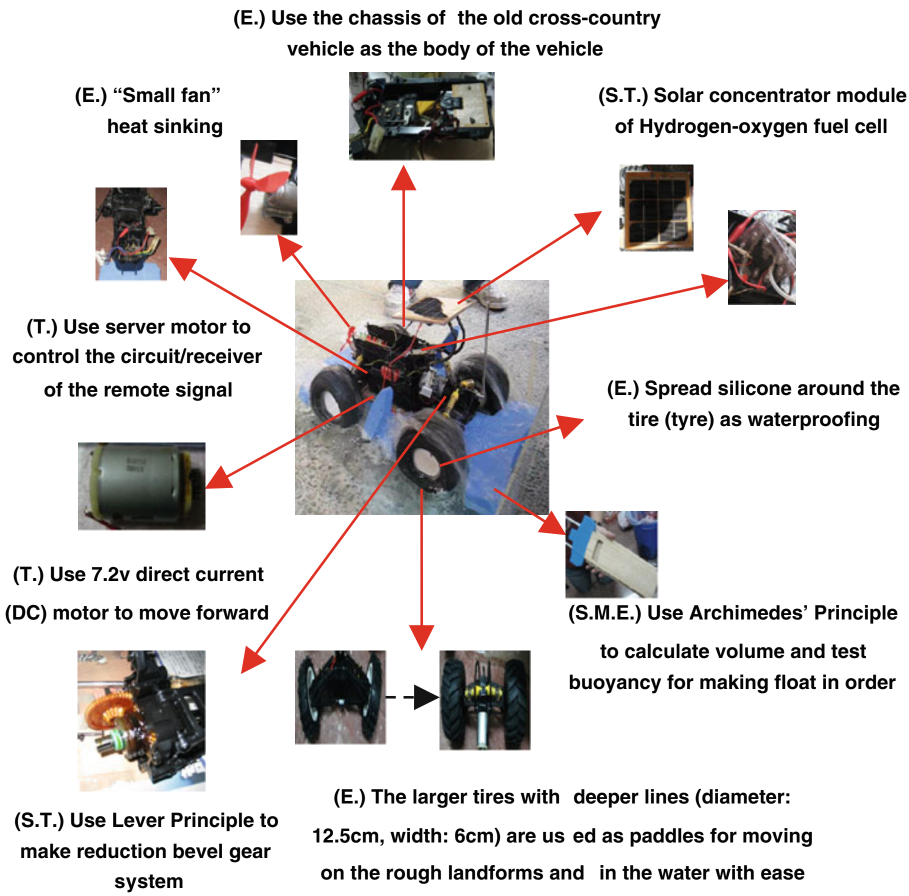


Fig. 1 The environmental protection electronic amphibian vehicle that produced by students

negative effects that technology brought to society and the environment. As a result, students suggested that one of the major issues in the current technology field is to develop technological techniques for environmental protection. The finding is consistent with the findings of Jenkins (2006)who argued that students identified that science and technology were important to society, health and life, although they raised environmental and social issues. Regarding career pursuits, students greatly recognized the positive effect of technology, and were willing to engage in related industries since it is one of the most popular current issues (Hendley et al. 1995). Furthermore, students had the most positive attitudes towards technology before having participated in the PjBL activity. However, students' positive attitudes had only a slight increase and were overtaken by engineering and science after the PjBL activity. The difference may be due to the fact that although students acquired more technology-related knowledge at school, they had no chance to understand the interrelationship and importance of STEM or to put theory into practice. Through the PjBL activity in this present study, students were not only able to apply the knowledge of STEM practically, but also to actually engage in a particular project that required them to understand and integrate the concept of STEM comprehensively.

Regarding student attitudes towards engineering, students also presented positive consequences. After participating in the PjBL activity, students' attitudes to engineering were higher than to the subjects of technology and science, and it became the most popular subject. Also, consistent results can be found from the interview that students had a positive impression of engineering. They suggested that engineering related knowledge and skills were the most widely and practically used of the four disciplines in the PjBL activity. This result suggested that PjBL strategy enhances student attitudes towards engineering and causes a significant change during the PjBL activity. The results is in accordance with the study by Bingolbali et al. (2007) which concluded that the PjBL activity was the major cause of raising student learning interest and motivation towards engineering. The interview results that indicate students were highly interested in engaging in the engineering industry may imply that PjBL had significant influence in student attitudes to future career pursuit.

For mathematics, students also had positive attitudes according to the results of the questionnaire. Comparing students' attitudes on STEM subjects with each other it was seen that students have similar interests in science, technology, and engineering. However, mathematics was the least popular subject within STEM both before and after PjBL activity. The results of the interview raise the issue that the majority of students found difficulties during mathematics education, even though they revealed positive attitudes to mathematics. Similar results can be seen in Stone et al.'s (2008) study. They argued that students' low interest in learning mathematics was due to the perceived difficulty of the subject. Moreover, Bingolbali et al. (2007) further suggested that the major reason for students' low interests in learning mathematics was because its principles are difficult and time consuming to understand. Furthermore, interview results suggested that interest in learning mathematics rose with increasing age. This is because students actually realized the importance of mathematics. They recognized that mathematics is a fundamental subject that is essential to learning, so they have to learn it even if it is difficult. Bingolbali et al. (2007) argued that the major reason for students wanting to learn mathematics was that it is strongly related to their further career and real world lives. Students who are planning to become mechanical engineers especially see mathematics as an important foundation of expertise. As a result, they tended to have positive attitudes towards mathematics. Even though the increase of students' interest towards mathematics is not significant, the results of the interviews show a different picture; students strongly feel the importance of mathematics after the PjBL activity. *The reason PjBL doesn't work well for mathematics* might be *because mathematics is time consuming and difficult to learn*. This might cause students to have insufficient competence to work well in mathematics compared to the other subjects. Educational authorities need to increase the effectiveness of instruction in mathematics in the future and further encourage an increase in learning interest.

Additionally, comparing the effectiveness of PjBL on STEM subjects after students implemented PjBL, the most effective subject is engineering, the second is science, the third is technology, and the least is mathematics. A curriculum combining PjBL with STEM could be applied to solve real world problems and to increase effectiveness in daily lives. Through this system of multidisciplinary teaching, students were more willing to learn STEM via PjBL's practical methods. Students were able to apply the knowledge of STEM practically and generated meaningful learning via the PjBL activity. Combining PjBL with STEM had influence in student attitudes towards future career pursuits. As a result, the students have a more positive attitude towards the important learning style of combining PjBL with STEM.

The application of this PjBL activity that integrated STEM had significant influence on students in terms of their positive attitudes towards STEM, and choices for future career pursuit. As a result, the study suggested that educators might be able to design appropriate PjBL's teaching strategy to raise students' learning interest, and further facilitate development and improvement in students essential to their future expertise.

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